2 June 1947

Report No. P.R. 30-29-6
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Navy Department, Bureau of Aeronautics

Washington, D.C.

MONTHLY PROGRESS REPORT FOR MAY, 1947

Contract No. NOa(s)8520

PULSE JET ENGINE

MARQUARDT AIRCRAFT COMPANY

VENICE, CALIFORNIA

2 June 1947

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Project 30-29

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PULSE JET ENGINE

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Reported by Harry W. Brown
Harry W. Brown
Project Engineer

and Merle Smallberg
Merle Smallberg
Research Engineer

Approved by Roy E. Marquardt
Roy E. Marquardt
President and Chief Engineer

Marquardt Aircraft Company
4221 So. Lincoln Boulevard
Venice, California

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[redacted]

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I SUMMARY

1. During the past month, Phase I involving Wind Tunnel tests of a standard 8 x 5.5 inch pulse jet engine was completed. A summary report on this work is now being distributed.

2. Drag measurements on the 8 x 5.5 inch engine with the submerged inlet cowl gave a drag coefficient varying from .35 to .39 in the duct closed case, and .49 in the duct open case. The calculated external drag coefficient was about .25.

3. Tests with a laminated vane utilizing .008 spring steel on the striking side, .005 beryllium copper in the center, and .006 spring steel on the outside gave static life of 2.5 hours. The valve life with ram air, while not as good as with static operation, is considerably greater than with the single leaf type valve.

4. Reduction in the valve area 14% increased the upper operating Mach number from about .55 to about .65. A total reduction of 29% increased the upper operating Mach number to about .80. The reduction in valve area caused a reduction in thrust in the lower Mach number region as compared to the standard valve box.

5. Measurements of operating frequency for a particular configuration at various Mach numbers showed little change occurring with Mach number up to M = .7. If anything, a slight decrease in the peak thrust operating frequency occurs.

6. It was found that increasing the vane tension has the same general effect as decreasing the valve area. That is, the upper operating Mach number is raised at some sacrifice in thrust at the lower Mach numbers.

7. It was found that a simple flared augmenter would give the same static thrust increase as the stepped type augmenter.

II NOMENCLATURE

8. The Bureau of Aeronautics (Reference 1) has re-defined the term net thrust as applied to pulse jet engines such that it now agrees with turbo-jet nomenclature. Under the former system, the net thrust was considered to be the thrust delivered by the engine after overcoming its own external drag. Under the new system, the net thrust is the thrust produced by the engine at a given air condition when the engine is not subject to external drag.

9. Gross and net thrusts are hereafter defined as follows:

$$\text{Gross thrust} = \frac{W_a + W_f}{g} V_j$$

$$\text{Net thrust} = \frac{W_a + W_f}{g} V_j - \frac{W_a}{g} V_o \qquad \text{where}$$

W_a = Weight flow of engine air, lbs./sec.

W_f = Weight flow of fuel, lbs./sec.

V_j = Average jet velocity, ft./sec.

V_o = Free stream air speed, ft./sec.

10. It is presumed that the net thrust as defined above is equal to the sum of the net scale reading of the test stand plus the external drag as defined in Appendix B of Reference 2. Therefore, in this and succeeding reports, the net scale reading of the test stand which was formerly identified as "net thrust" will be presented as "net thrust minus external drag." The computed value formerly presented as "gross thrust" (net scale thrust plus external drag) will now be called "net thrust."

III PROGRAM

11. During the past month, Phase 1 of the subject contract was completed. This phase involved "Wind tunnel tests of standard pulse jet engines and a report on the work accomplished." The summary report is now being reproduced for distribution. It is identified by Reference 2.

12. The remainder of the work carried on during the month has been on Phases 2 and 3, Phase 2 involves theoretical studies of subsonic pulse jet engines and phase 3, development testing of subsonic pulse jet engines.

13. Development testing during the month utilized for the most part an 8 x 5.5 inch pulse jet engine as shown in Figure 7 of Reference 3.

14. High speed tests were carried out at the U. S. Navy Wind Tunnel Laboratory at Fontana, California.

IV DEVELOPMENT TESTS

A. Submerged Inlet Cowl

15. In the previous monthly progress report, performance characteristics were presented for the standard engine when equipped with a submerged inlet cowl. (See Reference 4, Figures 3 and 12). Cold drag measurements were made on this engine in both the duct closed and duct open condition with internal airflow measurements being taken in the latter case. From this data, the external drag coefficient of the engine was calculated. This information is presented in Figure 4. For the method used to calculate the external drag coefficient, see Appendix B of Reference 2.

16. One of the purposes in mind in the design of this cowl was to raise the critical Mach number of the inlet on the presumption that an excessive drag rise might be occurring at relatively low operating speeds, thereby adversely affecting the thrust. A study of the drag coefficient curves shows that the submerged inlet unit does have a higher critical than the plain cowl, the break away point with the former in the duct closed position being about .7 and with the latter about .85 Mach number. The drag of this unit, however, is slightly higher than the plain cowl below .7 Mach number. This is most likely a result of the increased surface area and resulting skin friction with the submerged inlet.

17. Pressure coefficients on this cowl during cold flow testing are presented in Figures 5 and 6. With the duct open, the pressure coefficient over the outer surface of the inlet lip never reaches the critical coefficient. (See Figure 3.2, Reference 6). However, the critical point is reached at about $M_0 = .8$ on the central body. This indication of a shock formation is borne out by the force break in the drag coefficient curve at about $M = .85$ (Figure 4).

18. The pressure coefficients shown for the inner surface of the lip indicate sonic velocity is attained at about $M = .6$. However, this choking of the inlet is due to the large mass flow for the particular configuration tested. The actual peak air mass flow into the engine when operating is about one half the flow in these tests. Cold flow tests with the duct partially blocked to permit only the required mass flow will be made at a later date.

19. The pressure coefficients for the duct closed condition indicates the submerged body is shock-free up to about $M = .85$. The plot of coefficients over the lip is difficult to interpret in terms of streamlines. However, it is apparent that there are no compressibility troubles on the outer surface up to $M = .91$.

B. Beryllium Copper Laminated Vanes

20. Tests carried out by the Naval Research Laboratory have shown that the triple leaf type of valve has a considerably greater life than the standard single leaf type. These tests were made using a 14-inch diameter engine operating statically. No data have been published to date by N.R.L. on the beryllium copper laminated type vane, the knowledge of the development being obtained from a personal visit. Reference 4, however, does give data on a similar valve using a silicone-resin coated glass cloth center member instead of the beryllium copper. This construction was also tested and is discussed in section IV-C.

21. The tests made by Marquardt Aircraft Company were for the purpose of checking the reported valve life on a smaller diameter engine, also to see what effect, if any, ram pressure has on the valve life.

22. The beryllium copper laminated vane assembly used in the tests conducted to date consists of a .008-inch spring steel member on the striking side; a .005-inch beryllium copper, full hard temper in the center; and a .006-inch spring steel member on the combustion chamber side. The members are individually formed so as to be in the normally closed, no tension position. The units are not bonded together.

23. Performance with this valve is given in Figure 7. Performance with the same configuration but with .010 spring steel valves is given in Figure 12 of Reference 4. A comparison of the curves shows that statically, the thrust is increased with laminated vanes; at M = .2 and .3 performance is very similar and at M = .4, the specific fuel consumption and thrust are poorer. Operation above M = .4 was not possible. This indicates that the valve assembly had a tension less than the .010 single leaf type, thus allowing the induction of too great a volume of air at the higher speeds.

24. Regarding valve life, the engine was run statically for 2.5 hours at peak thrust without failure occurring. No drop-off in thrust occurred during this run. A corresponding continuous run has not yet been made at high speed, however, it was evident from the appearance of the valves after the runs had been made that deterioration is considerably accelerated under the high speed conditions. It appears that the life with ram air will be about 45 minutes. A check run is planned during future tests.

25. Fact . . believed to contribute to the improved life of this type valve include the following:

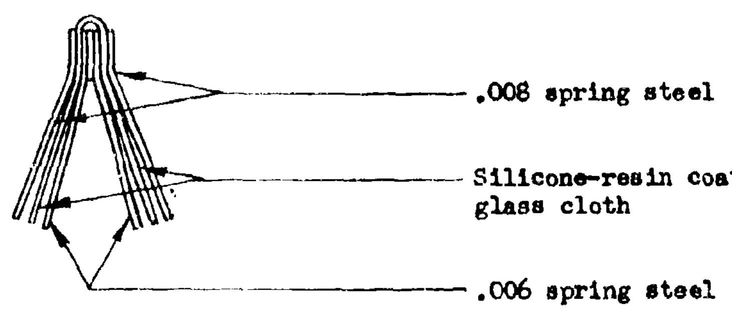
(a) The center member acts as a cushion to reduce the severity of impact loads on the striking vane.

(b) The center and outer members act as heat insulators to prevent direct contact between the combustion flame and the striking vane thus permitting the striking vane to operate at a lower temperature.

(c) Even if one or two of the members fail, the thrust is not adversely affected since the third member still provides a seal. Failure of the three members does not occur simultaneously but rather in a consecutive manner.

C. Plastic Laminated Vanes

26. This type valve is identical with the beryllium copper laminated type except that the center member is a .010-inch thick silicone-resin coated glass cloth material instead of the beryllium copper. The leaves were assembled in pairs as shown in the sketch below.



27. Performance tests of this type valve at M = .4 is given in Figure 8. Continuous life tests have not yet been made. The static thrust exceeded that for .010 steel vanes (Figure 12, Reference 4) by about 20%. At M = .4 peak thrust is off slightly and the specific fuel consumption worse, indicating less valve tension with resultant induction of larger volumes of air at a given speed.

28. A continuous life test has not yet been made. However, it appears that the life is as good as the beryllium copper laminated type.

D. Reduced Valve Area

29. To check the effect of valve entrance area on performance, two sets of runs were made, the first being with the valve area reduced 14% and the second with a 29% reduction. The blocking was done by replacing one and two, respectively, of the seven grid bars with solid blocks.

30. Figures 9, 10, and 11 show the effect of the blockage on performance. Three major effects were noted. First, decreasing the area raised the maximum speed at which the unit would operate. With the standard engine, the upper limit was about .4. Decreasing the area 14% raised the upper limit to a Mach number of about .65 and a 28% reduction to a Mach number of about .80. Secondly, the performance was much smoother at all speeds. Thirdly, reduction in the valve area reduced the thrust in the lower Mach number region as compared to the standard valve box. At M = .4 the measured reductions in net thrust for 14 and 29% blockage were 16 and 19% respectively.

31. In Figure 12 is shown the variation of operating frequency with fuel flow and speed from M = 0 to M = .69. The measurements were taken with the Frahm tachometer on the configuration with 29% of the valve area blocked.

32. Little, if any, variation in the operating frequency range with Mach number is evident from the data. At the lean limit the frequency is about 85-90 c.p.s., and at the rich limit about 40 c.p.s.

33. The trend of the data adds proof to the theory that for a given geometry, the volume of the inducted charge must not exceed a certain percentage of the total volume of the engine or resonance will not take place. For a given configuration, increasing the ram pressure causes an increase in the volume of the charge inducted per cycle until finally the critical ratio of inducted charge to engine volume is exceeded and resonance stops. Thus, it would appear that one means of obtaining maximum thrust at all forward speeds would be to provide some means for varying the entrance valve mechanism with increasing ram pressure such that the optimum inflow is obtained at all speeds. Varying the entrance area inversely with ram pressure or varying the valve tension directly with ram pressure should accomplish this purpose.

E. Vanes Normally Closed With Initial Tension

34. To check whether or not increasing the valve tension

would have the same general effect upon performance as decreasing the valve entrance area, a test was made using .012 inch vanes preformed so as to be .06 past the normally closed position prior to assembly of the vanes in the valve box. A considerable amount of initial tension thus existed. Data are presented in Figure 13.

35. It was found that the engine would operate up to a Mach number of about .8. Operation in general was quite similar to the operation with a 29% valve area block. The engine ran very smoothly, particularly in the range of .4-.7 Mach number; however, the external drag and internal thrust still equalled one another at a Mach number of about .6. It is believed that the effect of the increased tension was to cut down the inflow even more than the 29% valve block had done. A study of the data in Figure 13 justifies this assumption. For example, at M = .4 this configuration gave a peak-net thrust-external drag of about 16 pounds as compared to about 37 pounds with 29% block and 52 pounds with no block.

F. Smooth Flared Augmenter

36. To determine whether or not the steps in the standard "stepped" augmenter had any effect upon the thrust increase noted with the augmenter, a new augmenter was made up from a single piece of material with a simple flare having an exit area 16% greater than the tailpipe and the same length as the stepped augmenter. The exit of the stepped augmenter is 12% greater than the tailpipe. The plain flared augmenter is shown in Figure 3. Consecutive static runs were made; first with no augmenter, next with the stepped unit, and finally with the plain flared augmenter. No other changes existed. The results are shown in Figure 14.

37. The data shows no noticeable difference in performance between the stepped and simple flared augmenter, nor was any difference noticeable in the manner in which the unit operated. Accordingly, it is believed that the steps are unnecessary.

G. Pressure Cycle Analysis

38. Initial combustion chamber pressure measurements were made during the past month using the equipment shown in Figures 1 and 2. A brief description of the equipment and procedure for making the recordings follows:

39. The pickup used is a Statham unbonded electric strain gage differential pressure instrument with a range of 40 p.s.i. Batteries supply d.c. current to this pickup, the output of which is a d.c. voltage proportional to the differential pressure being measured. As the natural frequency of the unit is about 1,000 c.p.s., it will measure frequencies up to about 500 cycles accurately.

40. Connection of the pressure transmitter to the engine is made through a water cooled adapter as seen in Figure 2. This unit is essentially identical to the water cooled adapter used by the Naval Research Laboratory as described in Reference 5. The adapter is installed 6 inches back of the valve bank on the bottom side of the engine. A short length of heavy rubber hose connects the adapter to the pickup and serves to partially isolate the pressure transmitter from the vibration of the engine.

41. The voltage output from the Statham pressure transmitter is connected to the vertical amplifier of a Dumont oscilloscope. The deflection of the electron beam spot is then proportional to the instantaneous d.c. voltage output of the pressure pickup. A converted 16 mm. gun camera takes a continuous picture of the spot deflection while an argon bulb flashing at line frequency puts timing blips on the film at .02 second intervals.

42. A calibrating system is incorporated whereby resistors of the proper value are shunted across one leg of the strain bridge to give voltage outputs corresponding to 10, 20, and 30 p.s.i. Calibrations are made immediately upon shutting down the engine before the pickup temperature has had time to change. The calibration switch also has a position that shorts out the pickup to aid in zero pressure determination.

43. If the pickup bridge were balanced at the elevated temperatures encountered, the zero output line would be a zero pressure line, but as some unbalance exists, this means a small d.c. potential is present on the oscilloscope for zero pressure. The oscilloscope is only affected by this d.c. voltage at the instant it is applied or discontinued and by making use of this fact, it is possible to get a true zero pressure line. This characteristic has been used to locate the zero line shown on each of the traces presented.

44. Figures 15, 16, 17, and 18 present pressure recordings made with various configurations, and at various fuel flows and Mach numbers as noted. The measured net thrust, external drag, fuel flow, average maximum pressure, average minimum pressure, and cyclic frequency are noted under each record.

V THEORETICAL STUDIES

45. In conjunction with the design of the submerged inlet cowl, a basic aerodynamic study of high critical Mach number inlets has been made. An axial symmetric, incompressible flow study about an ellipsoidal nose attached to an infinite circular cylinder has been completed. Relaxation methods were used. The velocity distribution about the ellipsoidal configuration was compared with that about a blunt shaped nose defined by a source in a uniform stream. The results of this study may be taken as a first approximation for a numerical study of a steady or unsteady compressible flow about shapes suitable for pulse jet inlets.

46. In order to design a divergent engine that will achieve the high thrust per unit frontal area believed possible for this geometry, a thermodynamic analysis is being made. A solution of a set of one dimensional thermo-hydrodynamical non-linear differential equations formulated by Dr. J. K. L. MacDonald (Reference 7) for application to pulse jets has been started. The initial and boundary conditions are taken from experimental data on the 8-inch divergent engine already built. Numerical methods involving the use of characteristic theory are being used.

VI PROGRAM FOR THE COMING MONTH

Tests planned for the following month include the following:

1. Ducted pulse jet engine. An 8-inch engine submerged in an 11-inch duct is now nearing completion. The unit is designed to operate at M = .85. Tests of several different variations of the basic unit are planned.

2. A new "V" type valve box with 60% greater entrance area. This will be tested on both the standard and divergent engines.

3. At least two new tailpipe augmenter designs.
4. Variation in length of engine tailpipe.
5. A new engine having a cleaner external contour faired smoothly between the combustion chamber and the tailpipe.

6. A cowl designed to give low ram pressure recovery at the valve box.
7. A turbulence promoter installed within the combustion chamber behind the valve box. This unit has been designed from data supplied by Dr. McDonald and Dr. Hett of the Project Squid group at New York

University. Such a unit gave considerable increase in flame propagation speeds in tests conducted at the above mentioned organization.

8. An integral air starting device.
9. Variations in diameter of engine tailpipe.
10. Variations in geometry of the divergent engines.

VII VISITORS

47. Three parties affiliated with Project Squid have visited the Marquardt Aircraft Company of recent date. Problems of mutual interest pertaining to pulse jet engine developments were discussed. The visitors were:

1. Dr. J. K. L. MacDonald, Professor of Graduate Mathematical physics, New York University; Member, Technical Committee, and Chairman, Pulse Jet Panel, Project Squid.

2. Dr. John W. Hett, Research Associate, New York University; Experimental Research and Consultation, Project Squid.

3. Mr. J. G. Wilder, Jr. Senior Research Aerodynamicist, Propulsion Branch, Cornell Aeronautical Laboratory; Supervisor of Experimental Program for Pulse Jet Engines and Burner Laboratory, Project Squid.

VIII DISTRIBUTION

48. Distribution of this report is made in accordance with AN-GM Mailing List No. 3 dated May, 1947.

IX REFERENCES

1. Bureau of Aeronautics letter, Aer-PP-21 Serial 44504 dated 29 May 1947.

2. Marquardt Aircraft Company Report No. P.P.-3, "Summary Report Phase 1, Contract No. NOa(s)8520, Wind Tunnel Tests of an 8 x 5.5 Inch Pulse Jet Engine."

3. Marquardt Aircraft Company Report No. P.R. 30-29-4, "Monthly Progress Report for March, 1947, Contract No. NOa(s)8520, Pulse Jet Engine."

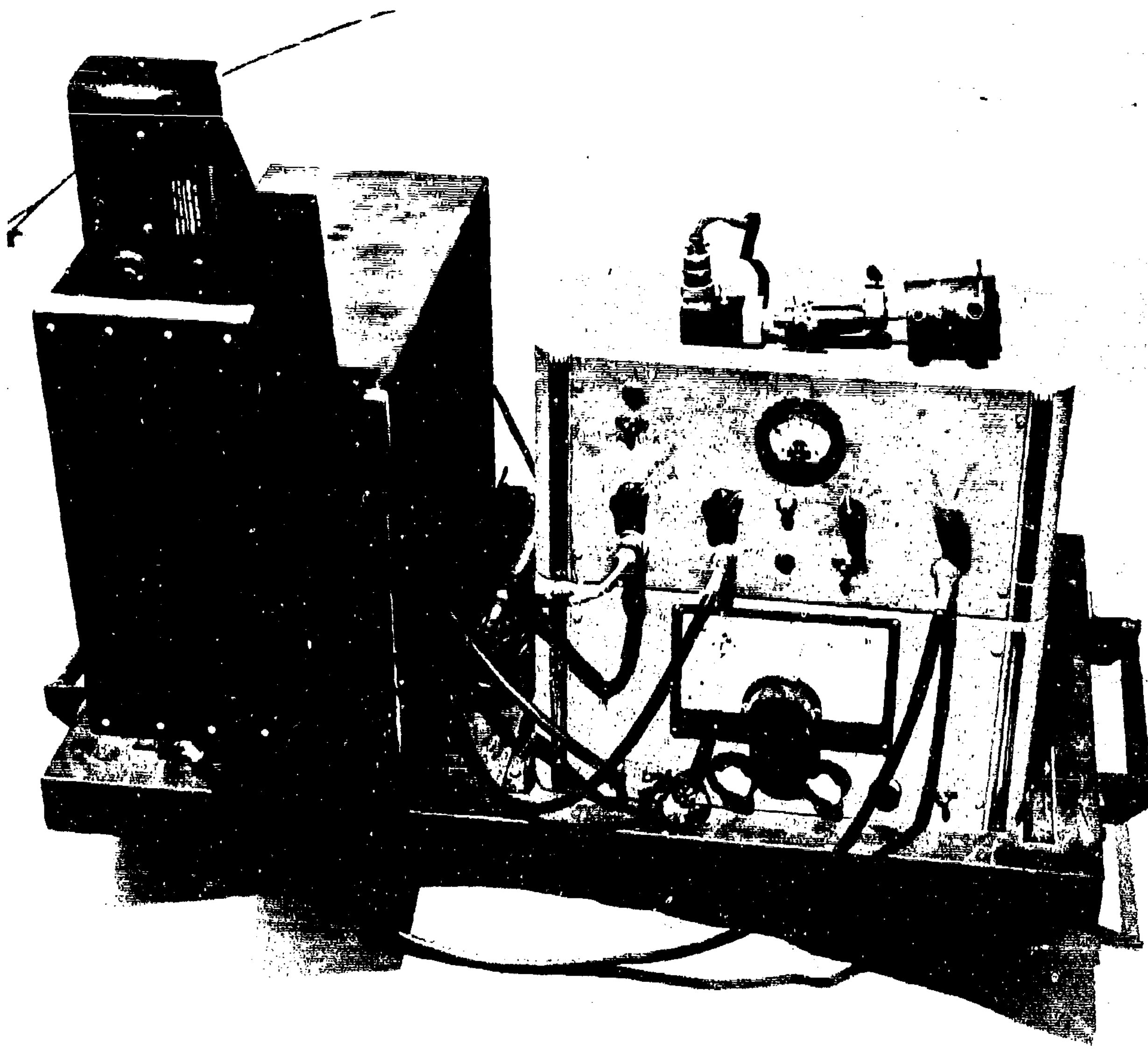
4. Marquardt Aircraft Company Report No. P.R. 30-29-5, "Monthly Progress Report for April, 1947, Contract No. NOa(s)8520, Pulse Jet Engine."

5. Naval Research Laboratory, Report No. 0-2730, "Partial Report on the Gas Pulsator," by L. F. Campbell and T. O. Meyer.

6. Liepman, H. W. and Puckett, A. E. Introduction to Aerodynamics of a Compressible Fluid, John Wiley and Sons, 1947.

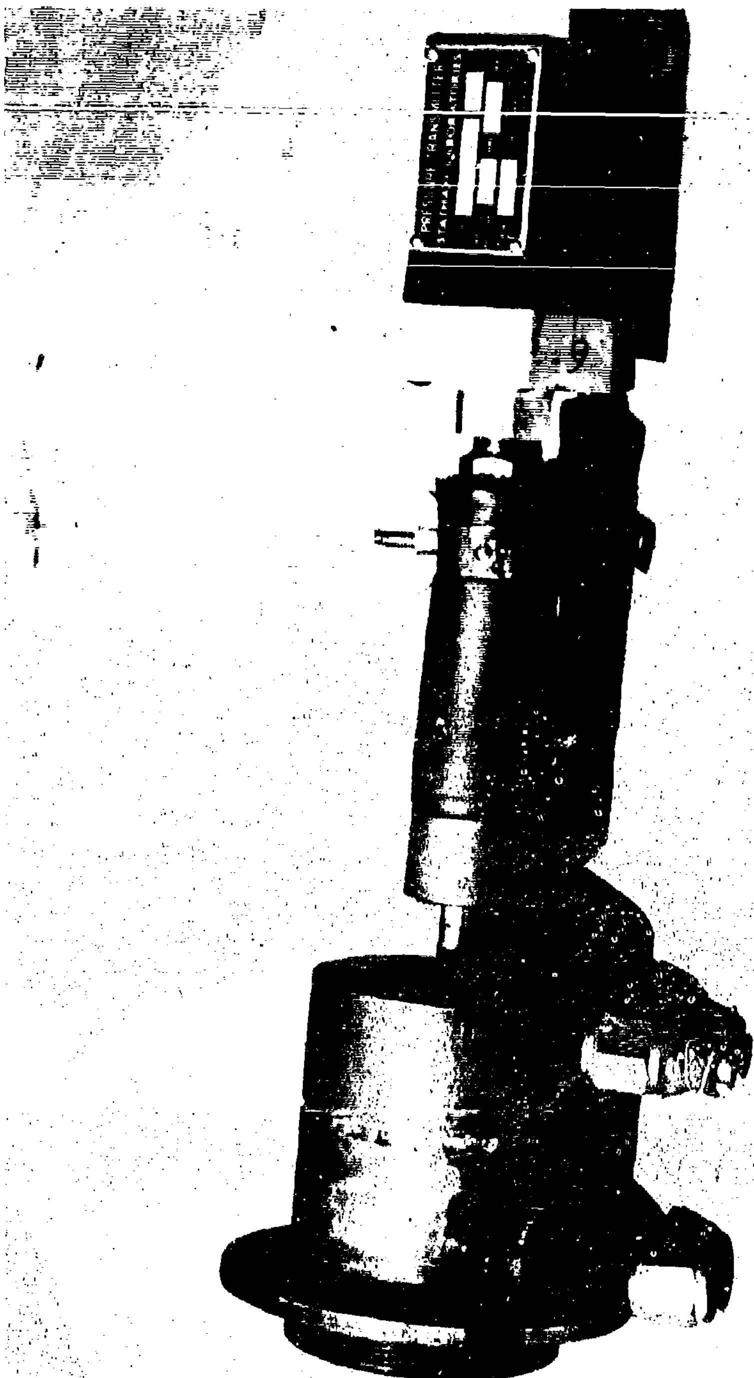
7. Institute for Mathematics and Mechanics, New York University, A Gas Dynamical Formulation for Waves and Combustion In Pulse Jets, by Dr. J. K. L. MacDonald, June 1946.

X INDEX OF FIGURES



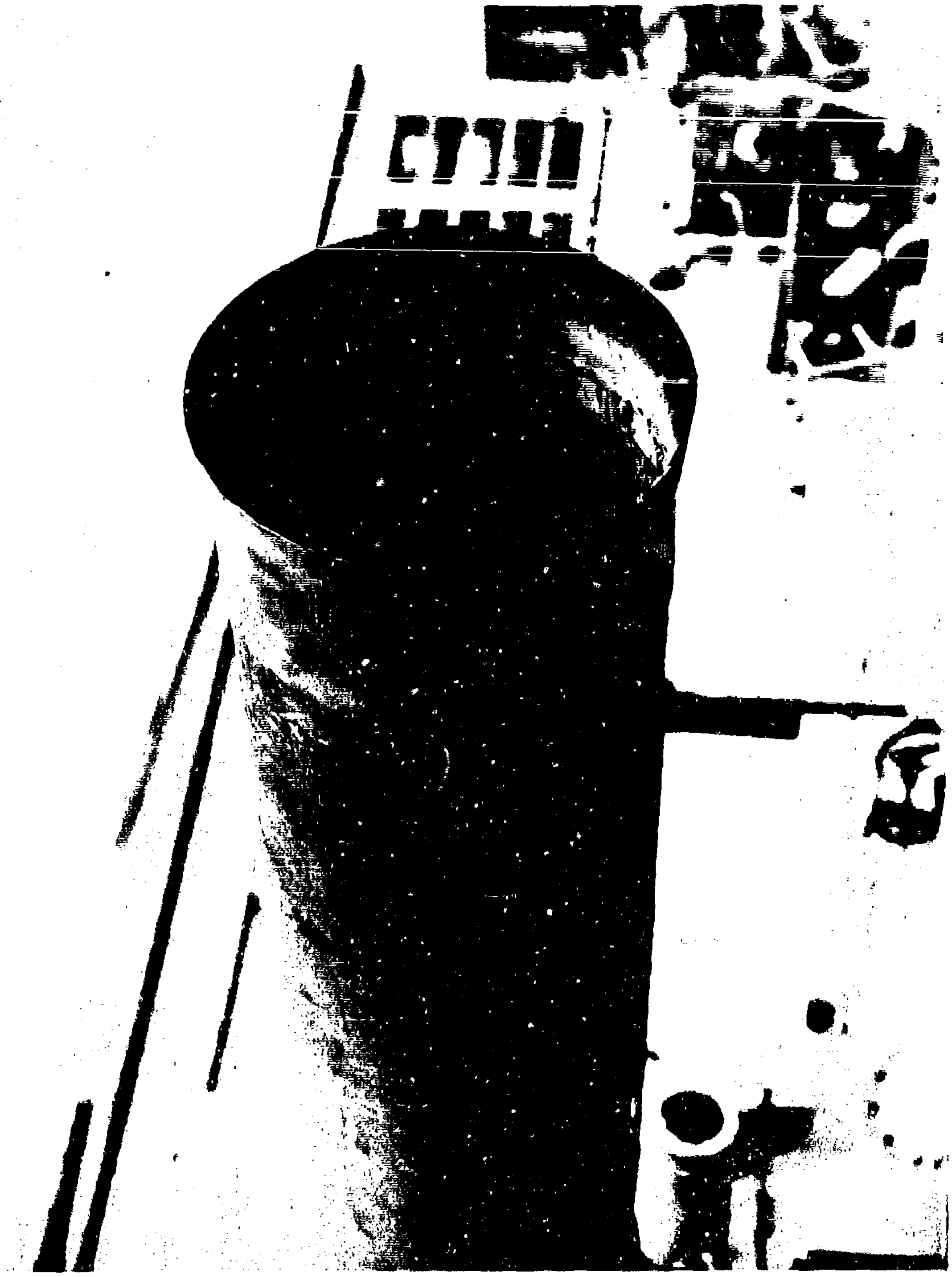
Pressure Cycle Measurement Instrumentation

Figure 1



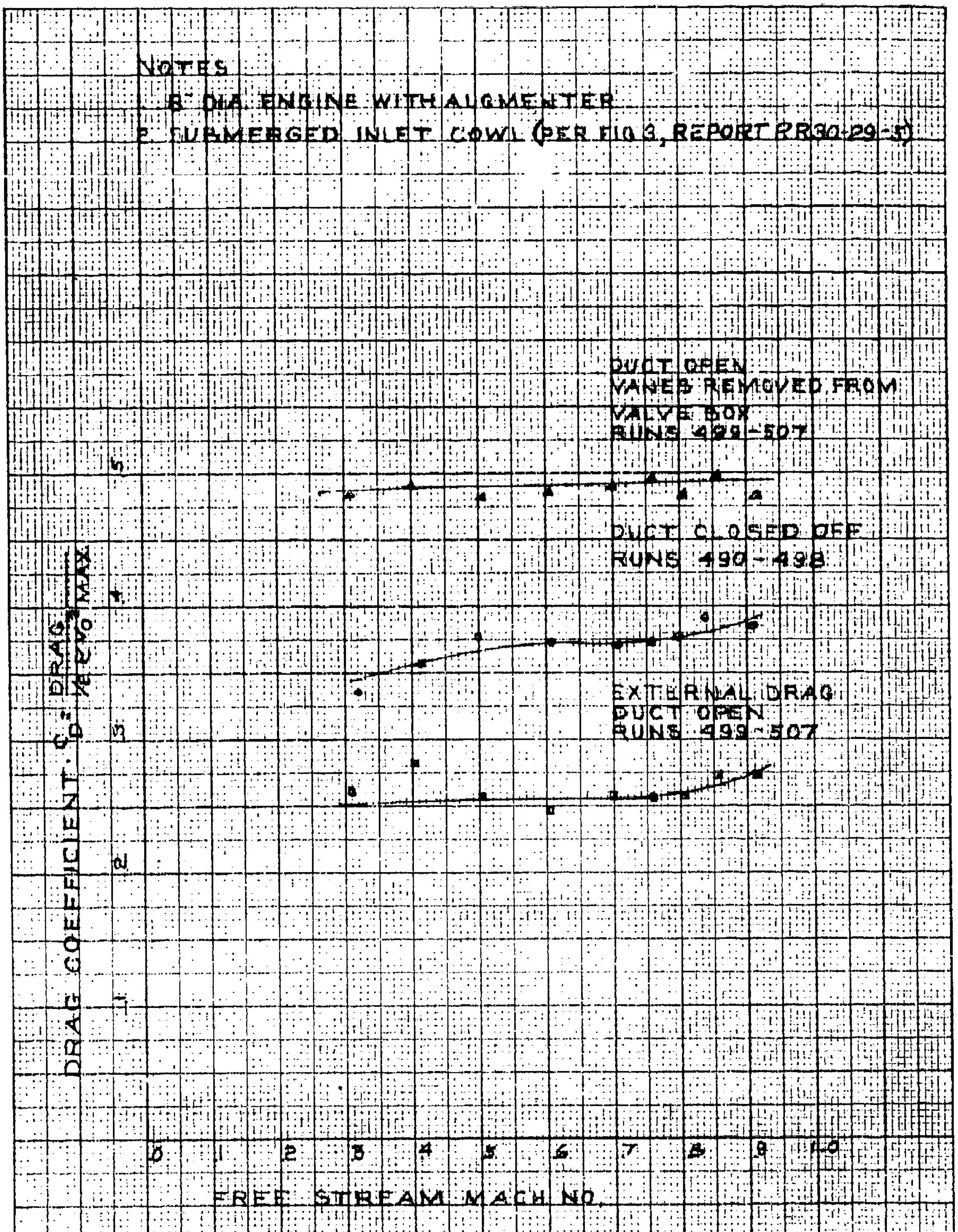
Water Cooled Adapter and Pressure Transmitter

Figure 2



Smooth Flared Augmenter

Figure 3



DRAG COEFFICIENTS FOR CONDITIONS AS NOTED

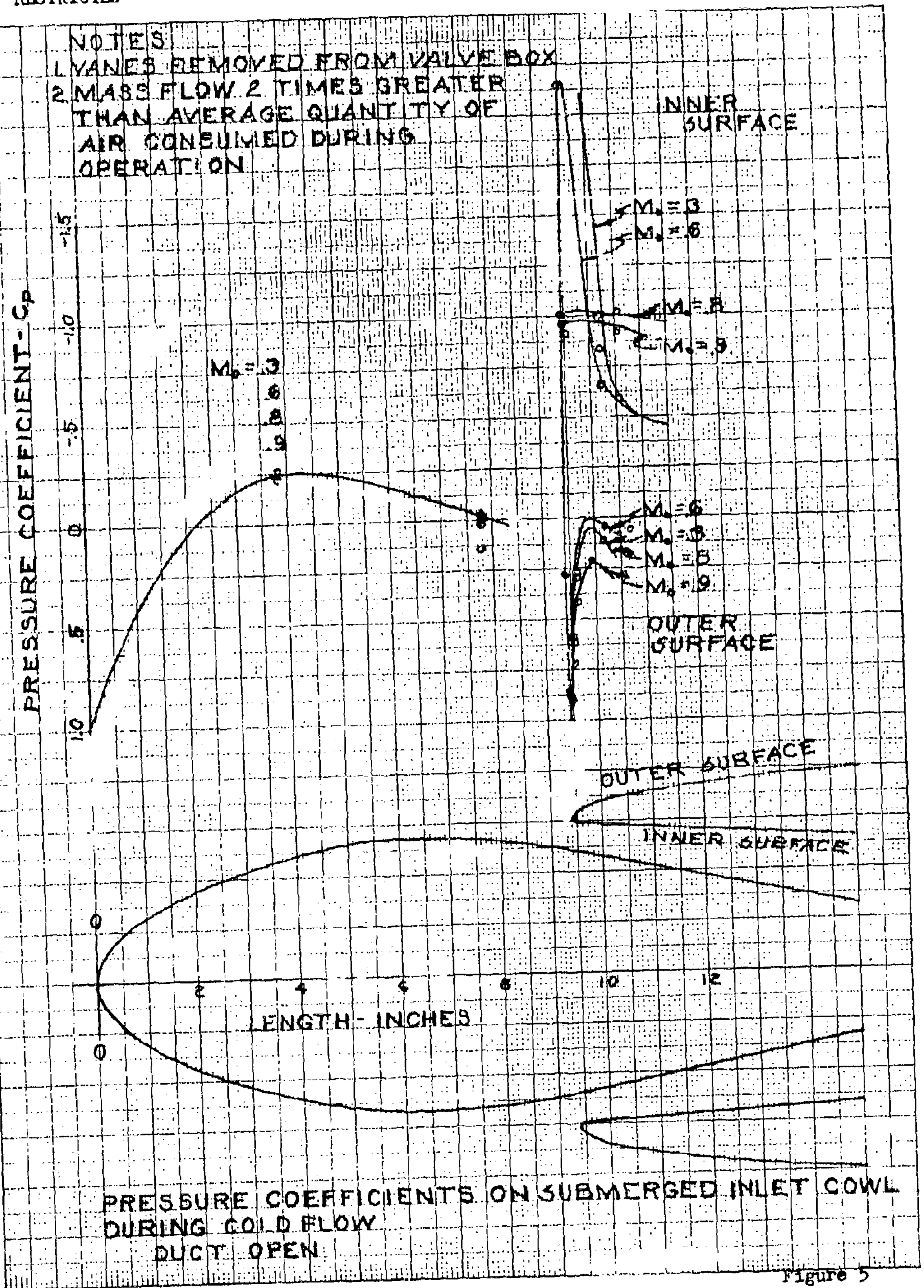
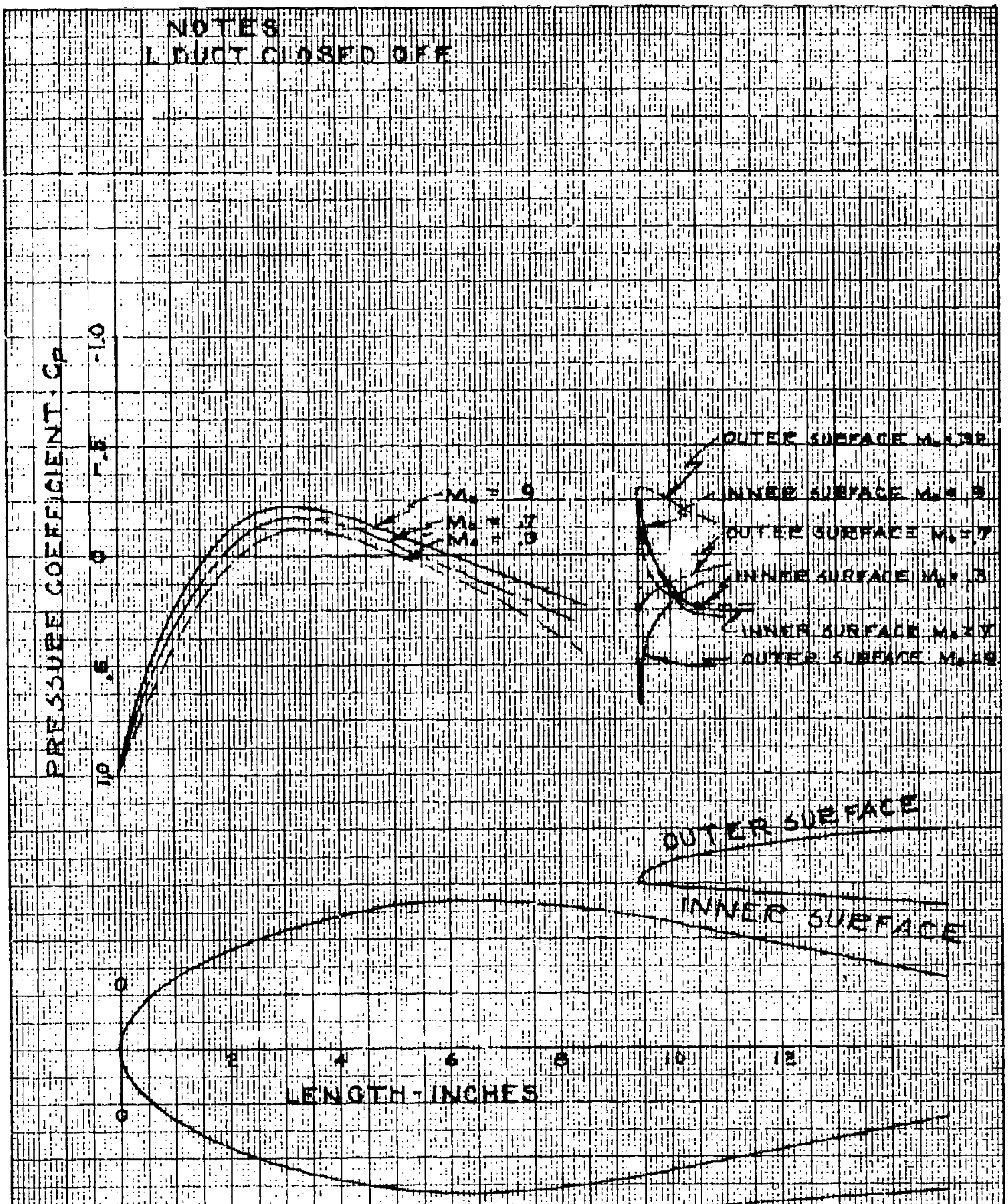

NOTES:
1. VANES REMOVED FROM VALVE BOX
2. MASS FLOW 2 TIMES GREATER THAN AVERAGE QUANTITY OF AIR CONSUMED DURING OPERATION
INNER SURFACE
M_o = .3
M_o = .6
M_o = .8
M_o = .9
PRESSURE COEFFICIENT - C_p
-1.5
-1.0
-.5
0
.5
1.0
M_o = .3
.6
.8
.9
M_o = .6
M_o = .3
M_o = .8
M_o = .9
OUTER SURFACE
OUTER SURFACE
INNER SURFACE
0
2
4
6
8
10
12
LENGTH - INCHES
0
PRESSURE COEFFICIENTS ON SUBMERGED INLET COWL DURING COLD FLOW
DUCT OPEN

Figure 5



PRESSURE COEFFICIENTS ON SUBMERGED INLET COWL
DURING COLD FLOW
·DUCT CLOSED·

Figure 6

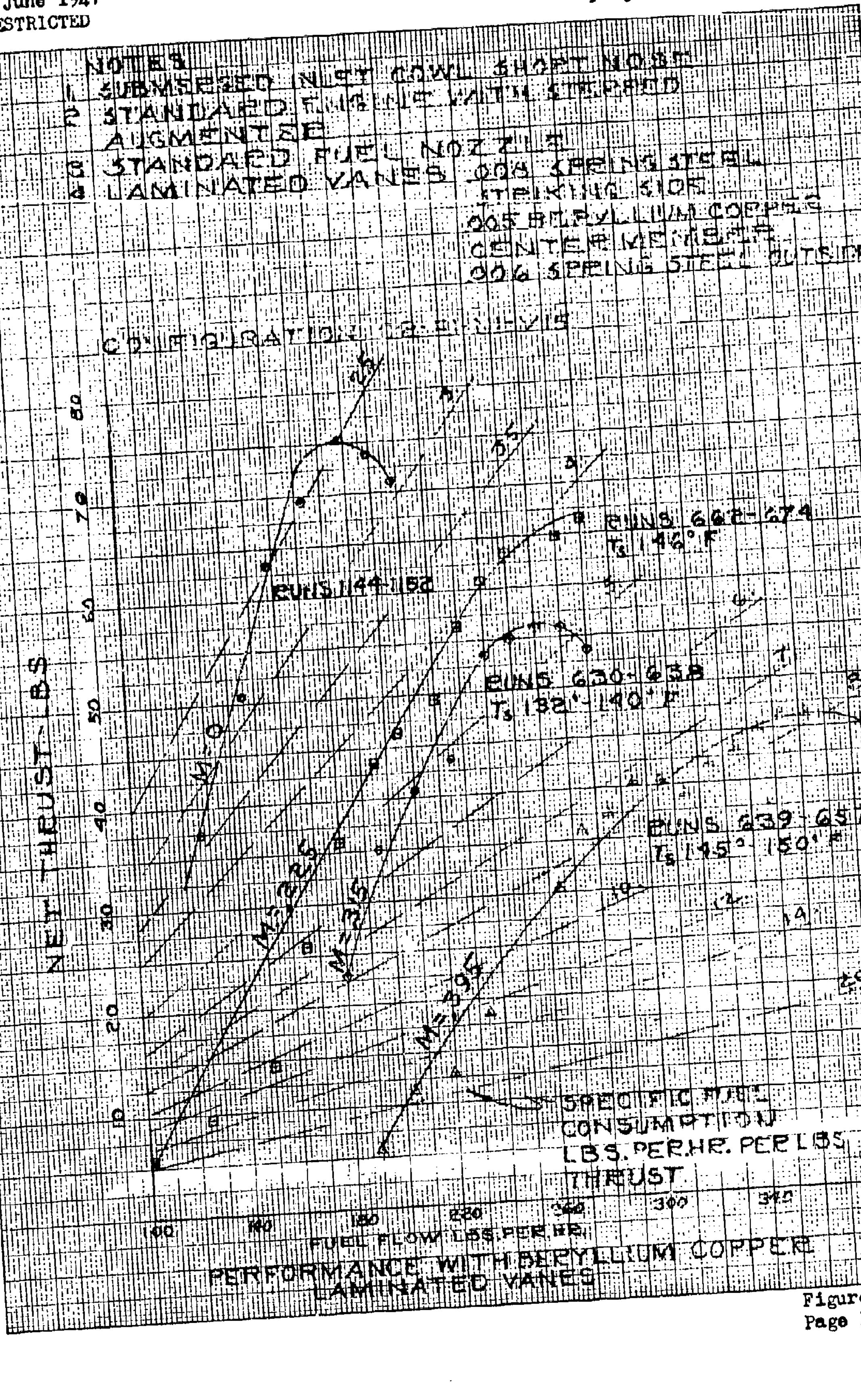
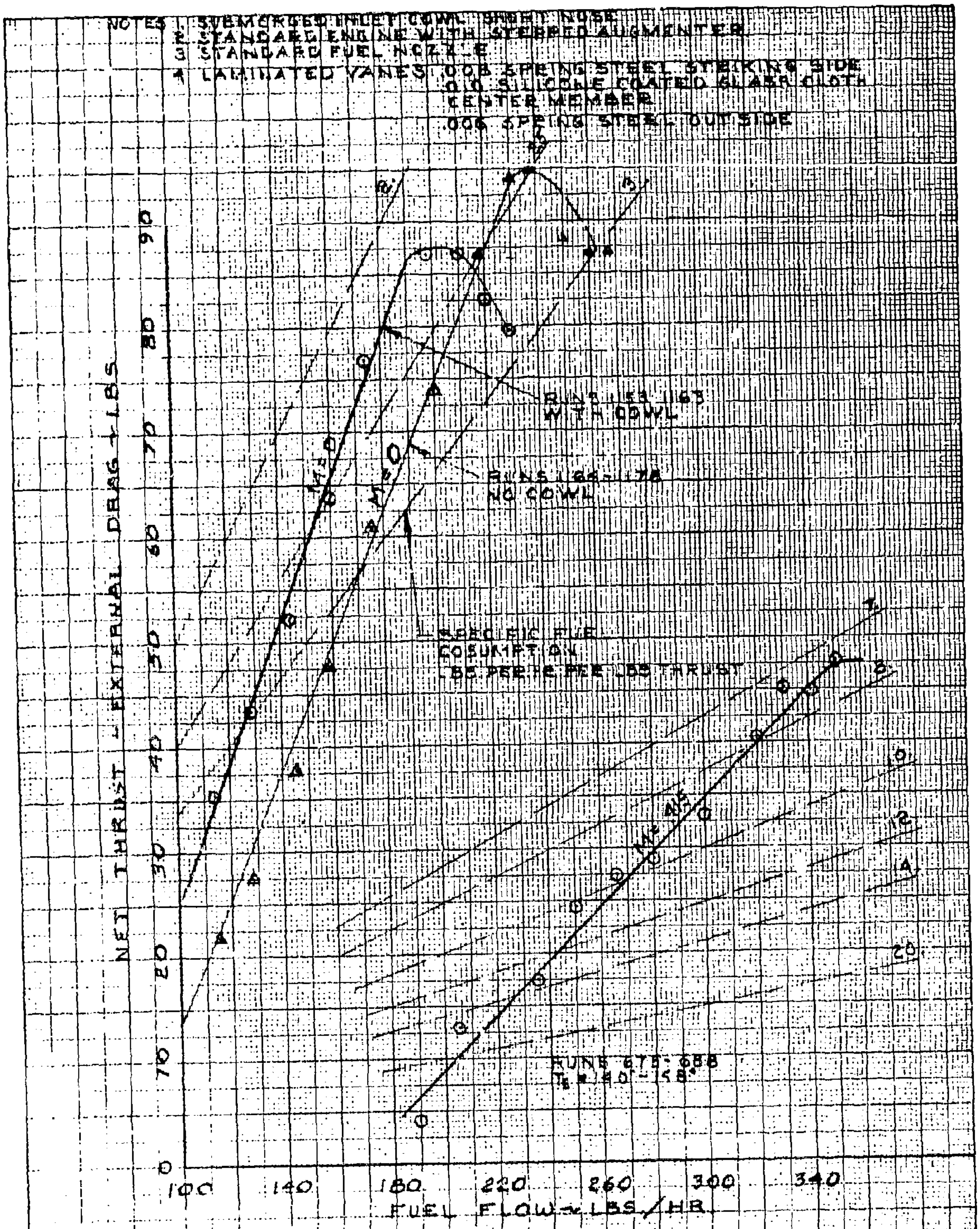

NOTES
3 STANDARD FUEL NOZZLE
4 LAMINATED VANES
CENTER
RUNS 144-152
RUNS 662-674
RUNS 630-638
T_3 132°-140° F
RUNS 639-657
T_3 145°-150° F
NET THRUST LBS
M=0
M=.225
M=.315
M=.395
SPECIFIC FUEL
CONSUMPTION
LBS. PER HR. PER LBS.
THRUST
100
140
180
220
260
300
340
10
20
30
40
50
60
70
80
FUEL FLOW LBS. PER HR.
PERFORMANCE WITH BERYLLIUM COPPER
LAMINATED VANES

Figure 7



PERFORMANCE WITH LAMINATED VANES UTILIZING
.010 SILICONE COATED GLASS CLOTH CENTER MEMBER
CONFIGURATION C2-E1-N1-V16

Figure 8

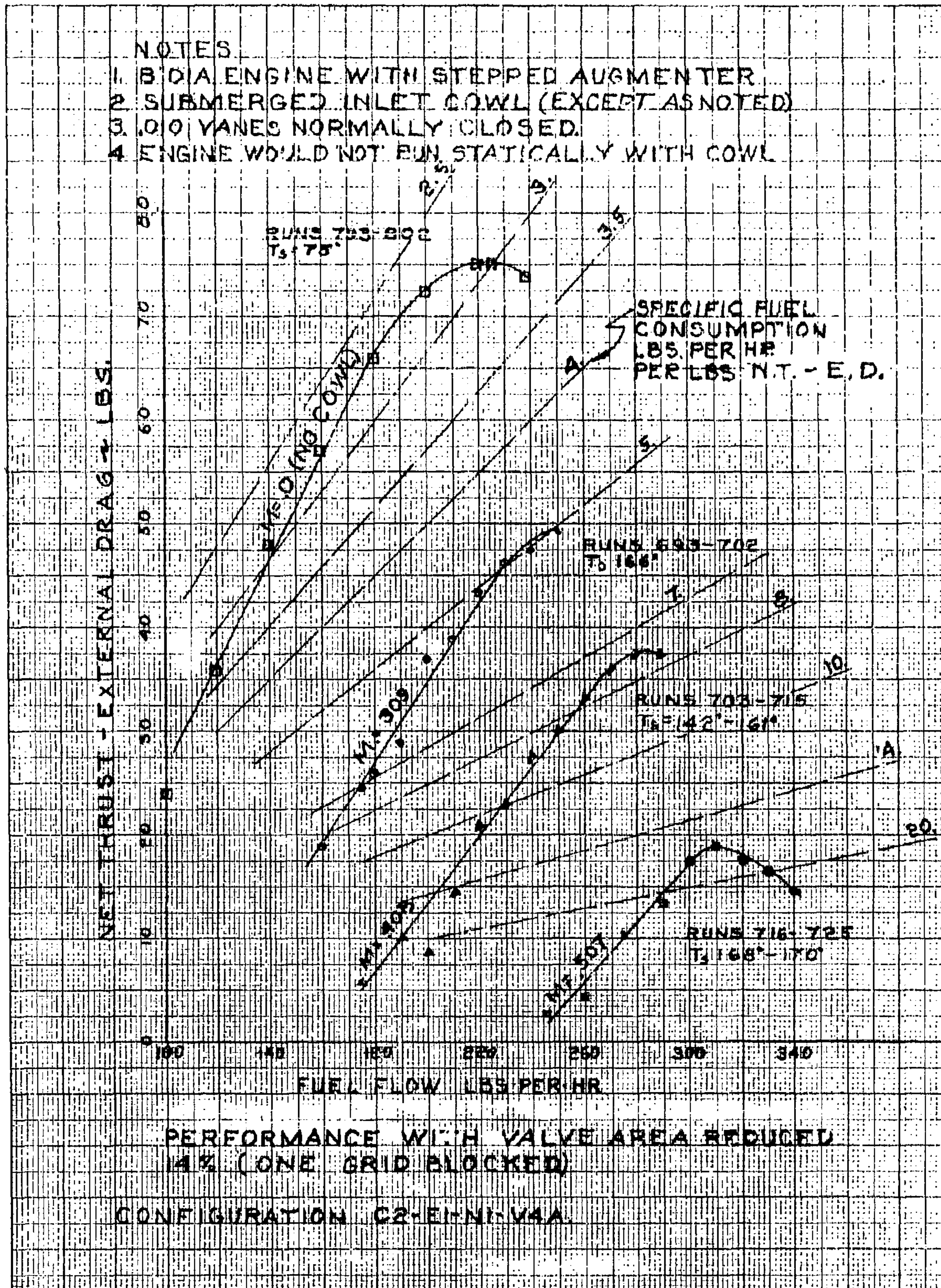
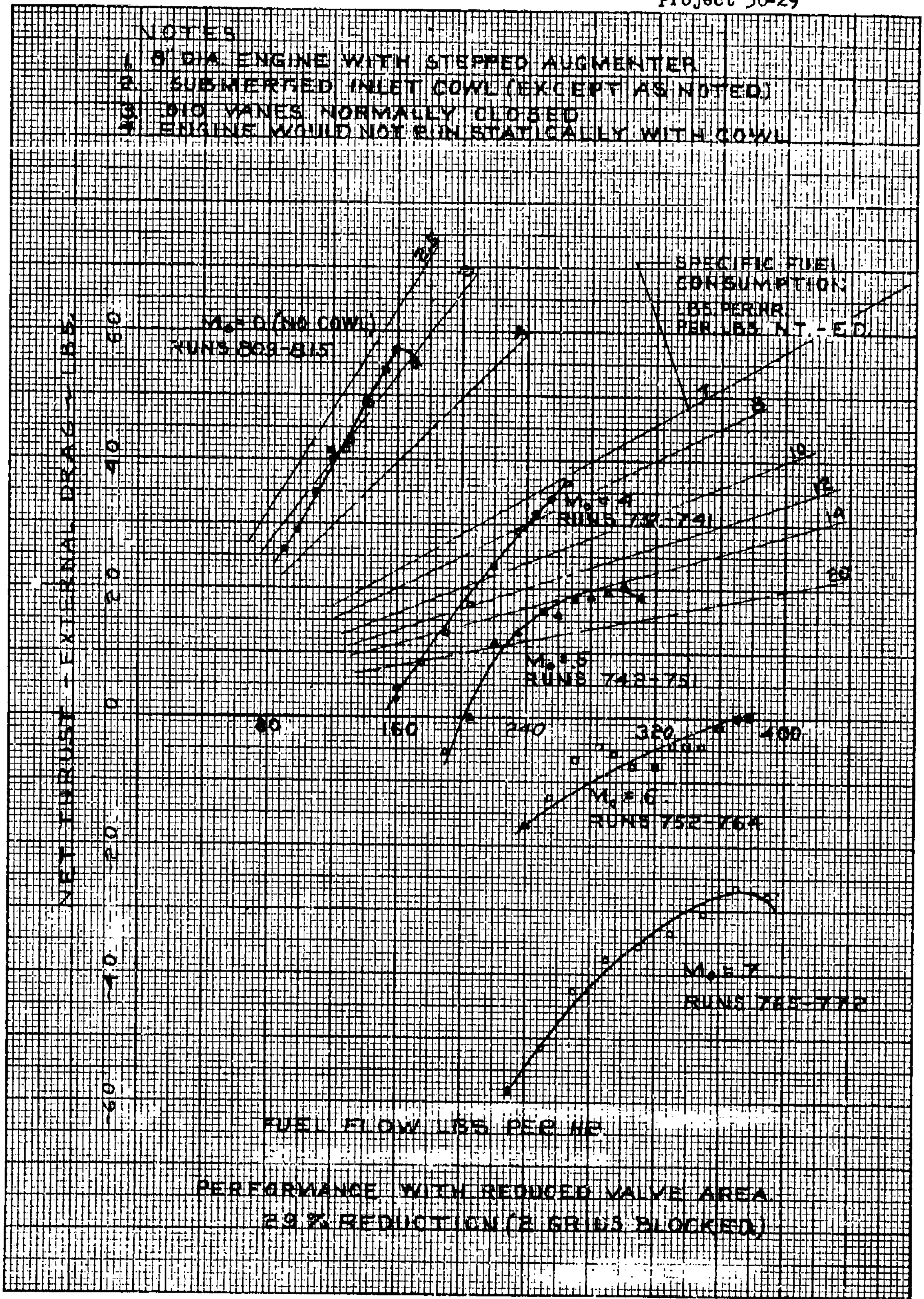
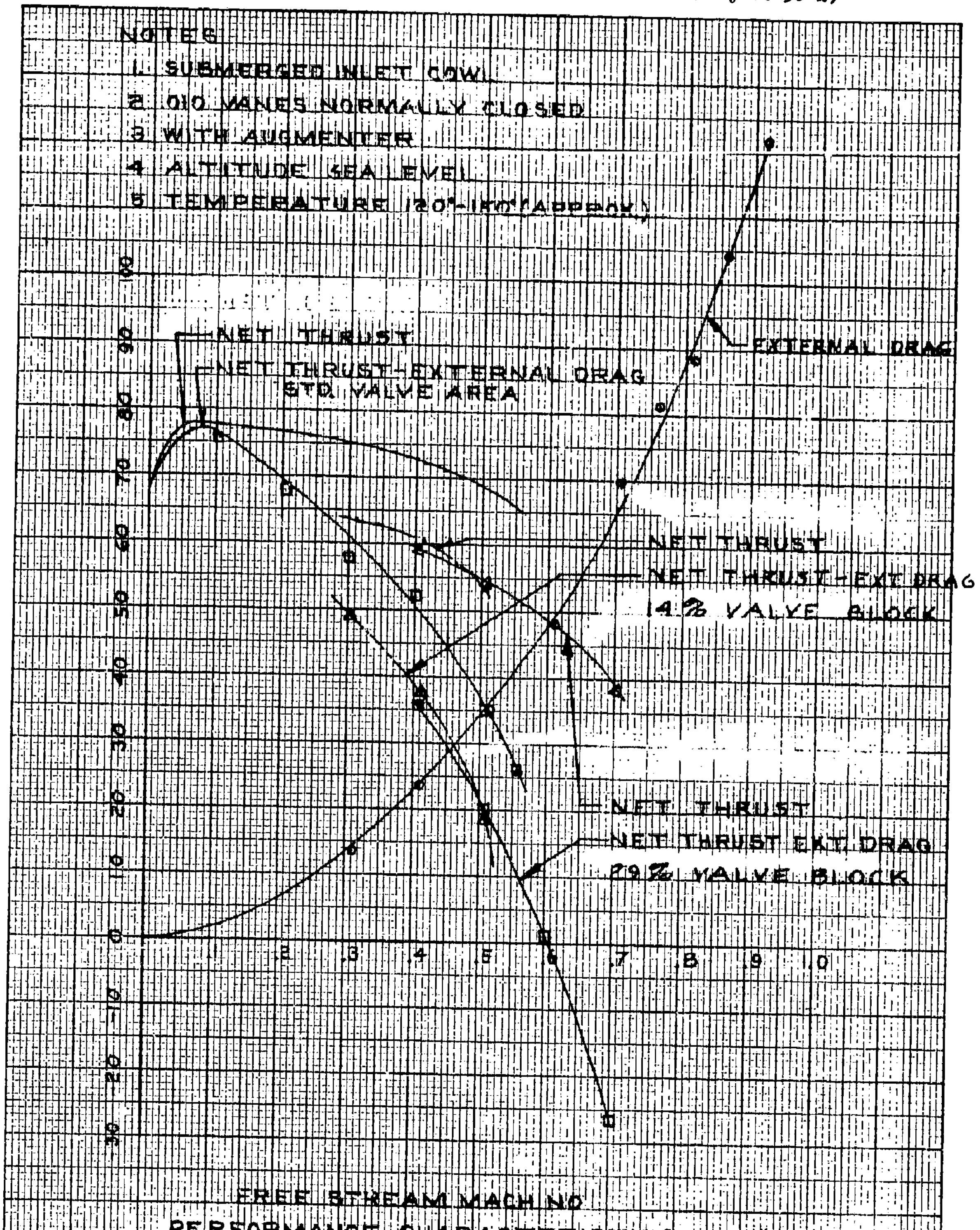

NOTES
1. 8" DIA. ENGINE WITH STEPPED AUGMENTER
2. SUBMERGED INLET COWL (EXCEPT AS NOTED)
3. O.O. VANES NORMALLY CLOSED
4. ENGINE WOULD NOT RUN STATICALLY WITH COWL
SPECIFIC FUEL CONSUMPTION LBS. PER HR PER LBS. N.T. - E.D.
RUNS 693-702
RUNS 703-715
RUNS 716-725
M=0 (NO COWL)
M=.309
M=.207
NET THRUST - EXTERNAL DRAG ~ LBS.
FUEL FLOW LBS PER HR
PERFORMANCE WITH VALVE AREA REDUCED 14% (ONE GRID BLOCKED)
CONFIGURATION C2-E1-N1-V4A

Figure 9

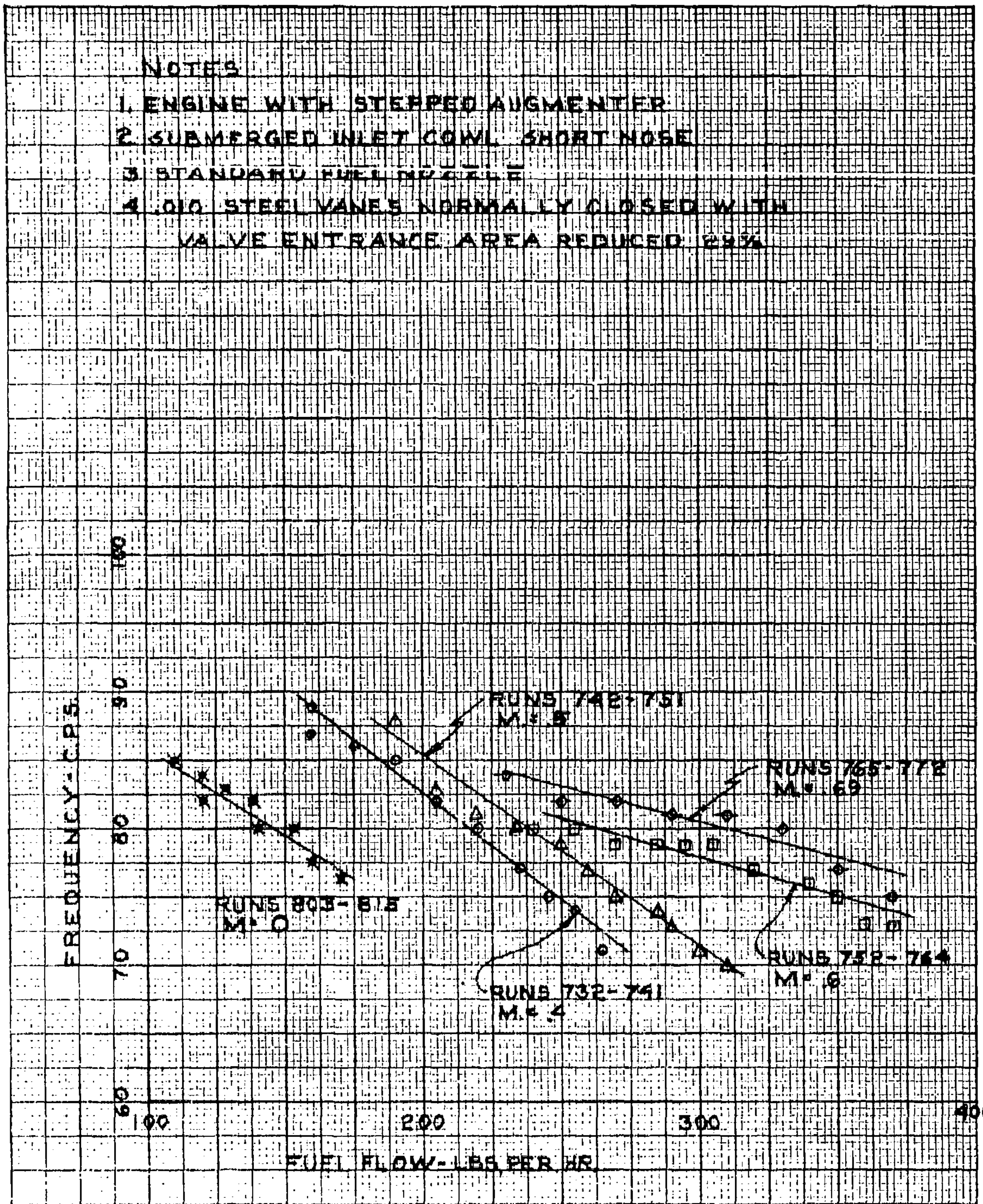


PERFORMANCE WITH REDUCED VALVE AREA
29 % REDUCTION (2 GRIDS BLOCKED)

Figure 10

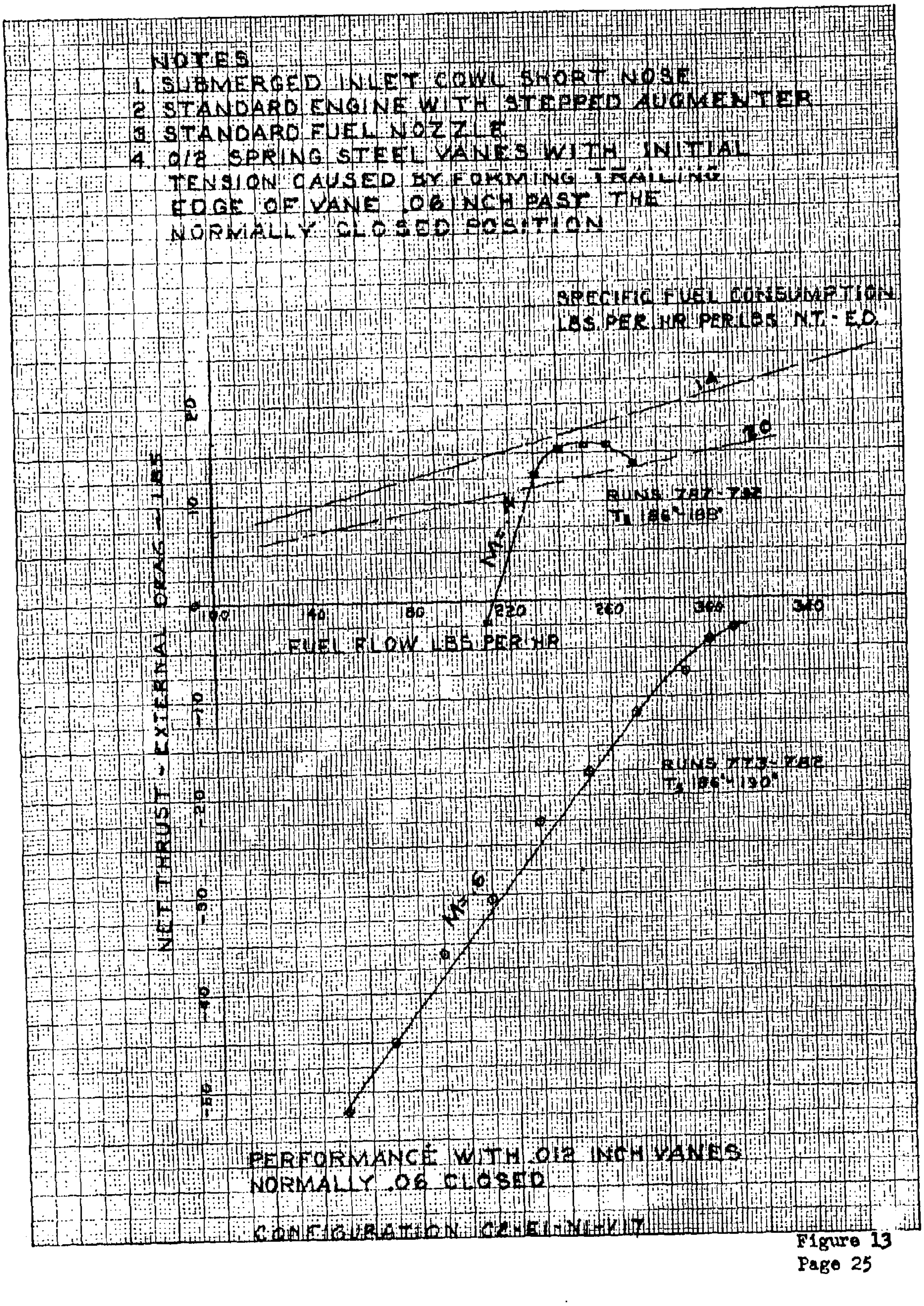


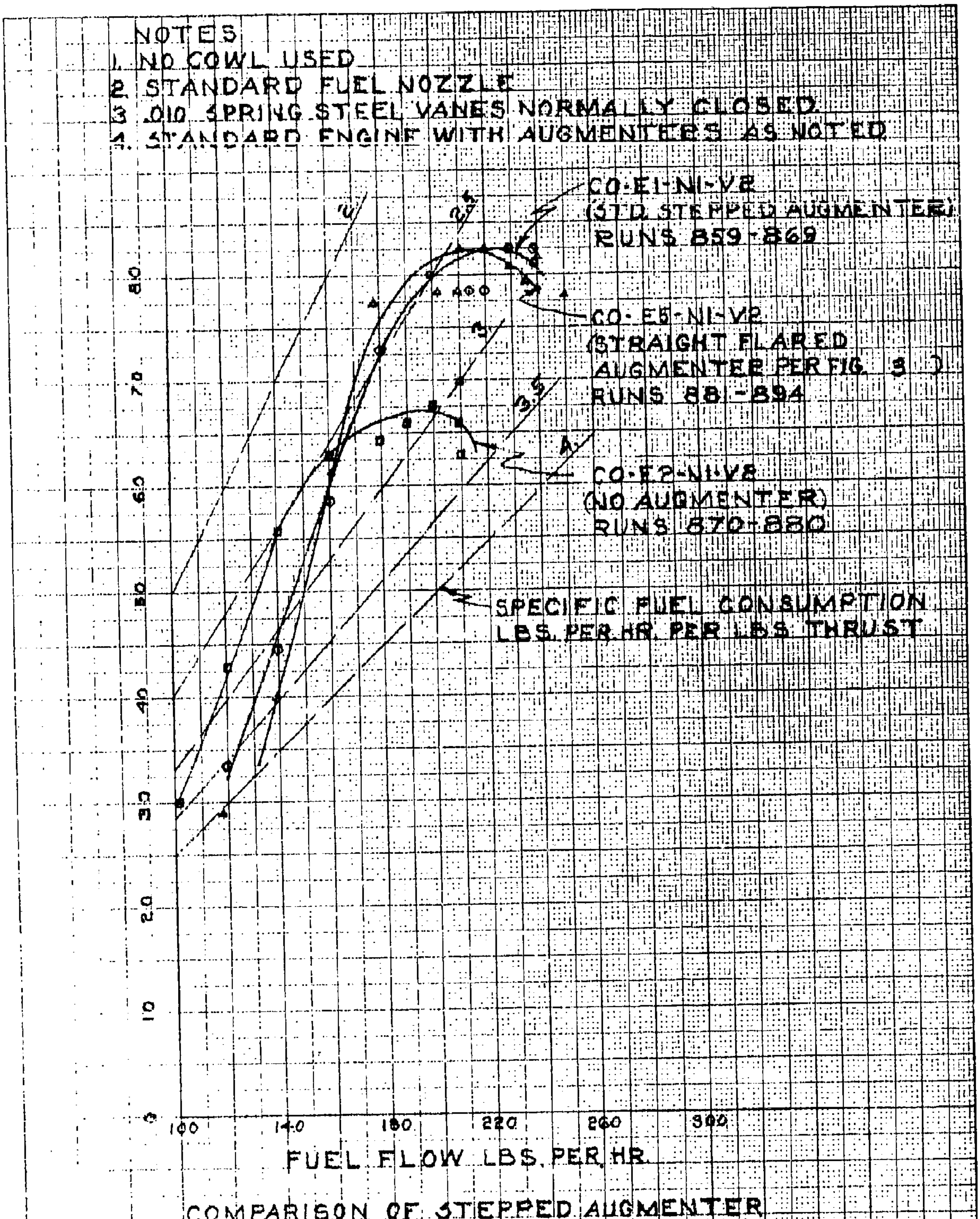
PERFORMANCE CHARACTERISTICS OF 8"x 5.5" ENGINE WITH SUBMERGED INLET COWL



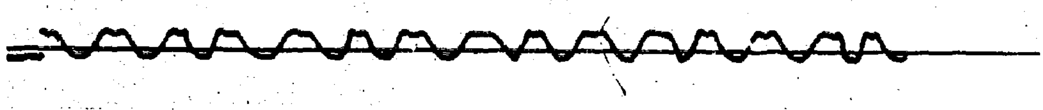
VARIATION OF FREQUENCY WITH FUEL FLOW AND SPEED

CONFIGURATION C2-E1-N1-V4B


NOTES
1. SUBMERGED INLET COWL SHORT NOSE
2. STANDARD ENGINE WITH STEPPED AUGMENTER
3. STANDARD FUEL NOZZLE
4. .012 SPRING STEEL VANES WITH INITIAL TENSION CAUSED BY FORMING TRAILING EDGE OF VANE .06 INCH PAST THE NORMALLY CLOSED POSITION
SPECIFIC FUEL CONSUMPTION LBS PER HR PER LBS NT - ED
RUNS 773-782
NET THRUST - EXTERNAL DRAG - LBS
FUEL FLOW LBS PER HR
PERFORMANCE WITH .012 INCH VANES NORMALLY .06 CLOSED



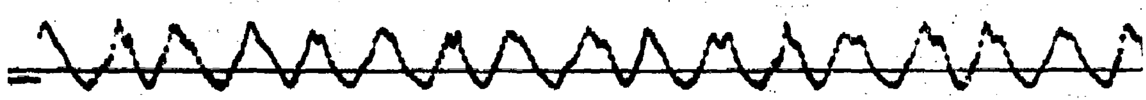
COMPARISON OF STEPPED AUGMENTER
AND PLAIN FLARED AUGMENTER



Pict. No. C1
Run No. 662
Config. C2-E1-N1-V15

Mach No. = .225
N.T.-E.D. = 5.8 #
Fuel Flow = 120 pph.

Av. Max. Pres. = 5.4 psig.
Av. Min. Pres. = -1.6 psig.
Freq. = 90 cps.



Pict. No. D1
Run No. 667
Config. C2-E1-N1-V15

Mach No. = .225
N.T.-E.D. = 43.5 #
Fuel Flow = 195 pph.

Av. Max. Pres. = 15.9 psig.
Av. Min. Pres. = -4.8 psig.
Freq. = 80 cps.

Pict. No. E1
Run No. 673
Config. C2-E1-N1-V15

Mach No. = .225
N.T.-E.D. = 65.2 #
Fuel Flow = 260 pph.

Av. Max. Pres. = 20.9 psig.
Av. Min. Pres. = -6.4 psig.
Freq. = 67 cps.

Pict. No. F1
Calibration Run for Pict. No. C1, E1, and D1

Combustion chamber pressures for engine with augmenter, submerged inlet cowl, beryllium copper laminated vanes, at M = .225

Figure 15

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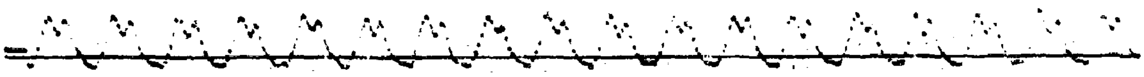
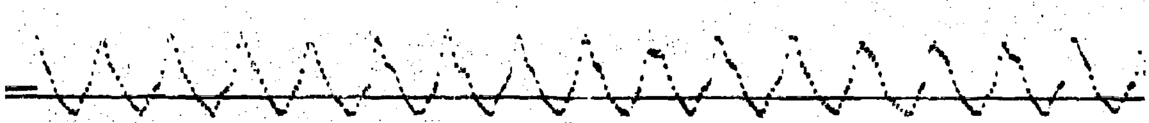
Project 30-29



Pict. No. B4
Run No. 733
Config. C2-E1-N1-V4B

Mach No. = .408
N.T.-E.D. = 2.9 #
Fuel Flow = 160 pph.

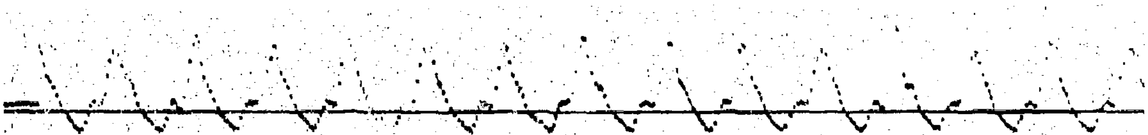
Av. Max. Pres. = 13.1 psig.
Av. Min. Pres. = -2.7 psig.
Freq. = 87 cps.



Pict. No. C4
Run No. 738
Config. C2-E1-N1-V4B

Mach No. = .408
N.T.-E.D. = 29.0 #
Fuel Flow = 235 pph.

Av. Max. Pres. = 19.8 psig.
Av. Min. Pres. = -5.9 psig.
Freq. = 77 cps.



Pict. No. D4
Run No. 741
Config. C2-E1-N1-V4B

Mach No. = .408
N.T.-E.D. = 36.3 #
Fuel Flow = 265 pph.

Av. Max. Pres. = 21.4 psig.
Av. Min. Pres. = -6.2 psig.
Freq. = 71 cps.

Pict. No. E4
Calibration Run for Pict. No. B4, C4, and D4

Combustion chamber pressures for engine with augmenter, submerged inlet cowl, .010 vanes normally closed, 29% valve area block at M = .408.

Figure 16

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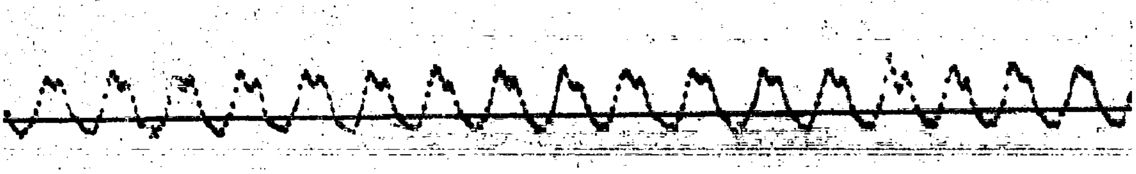
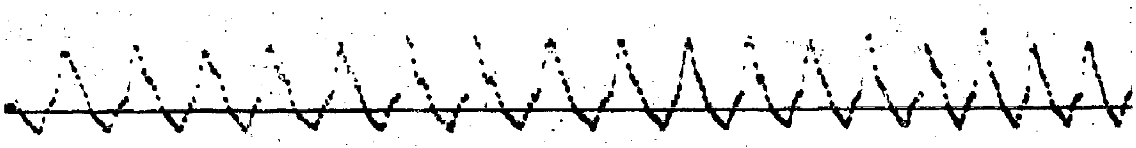
P.R. 30-29-6
Project 30-29



Pict. No. F4
Run No. 742
Config. C2-E1-N1-V4B

Mach No. = .504
N.T.-E.D. = -5.0 #
Fuel Flow = 190 pph.

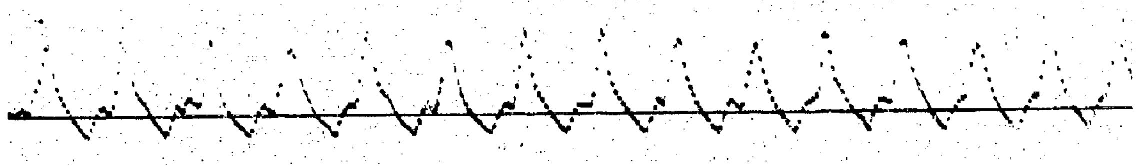
Av. Max. Pres. = 14.7 psig.
Av. Min. Pres. = -4.8 psig.
Freq. = 85 cps.



Pict. No. G4
Run No. 746
Config. C2-E1-N1-V4B

Mach No. = .504
N.T.-E.D. = 16.7 #
Fuel Flow = 250 pph.

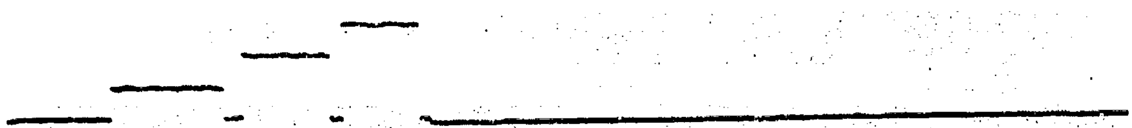
Av. Max. Pres. = 21.4 psig.
Av. Min. Pres. = -5.9 psig.
Freq. = 76 cps.



Pict. No. H4
Run No. = 751
Config. C2-E1-N1-V4B

Mach No. = .504
N.T.-E.D.= 20.3 #
Fuel Flow = 300 pph.

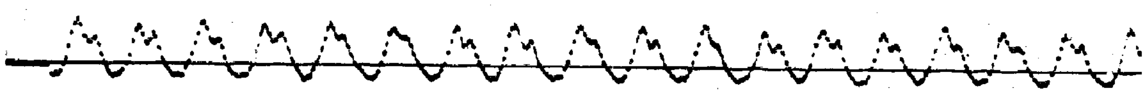
Av. Max. Pres. = 24.6 psig.
Av. Min. Pres. -6.4 psig.
Freq. = 71 cps.



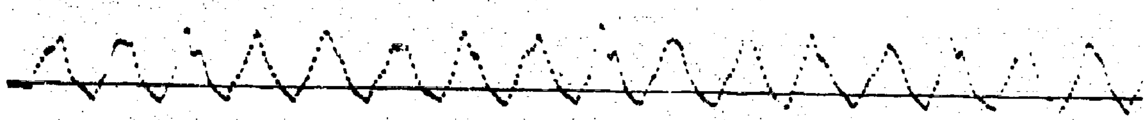
Pict. No. L4
Calibration for F4, G4, N9, I4, J4, K4.

Combustion chamber pressures for engine with augmenter. Submerged inlet cowl, .010 vanes normally closed, 29% valve area block at M = .504.

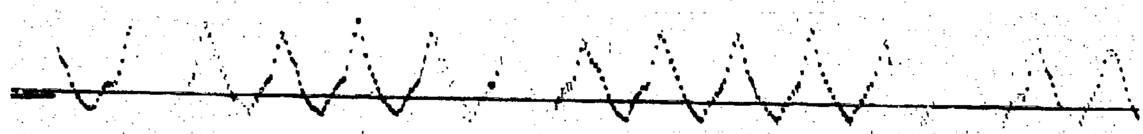
Figure 17



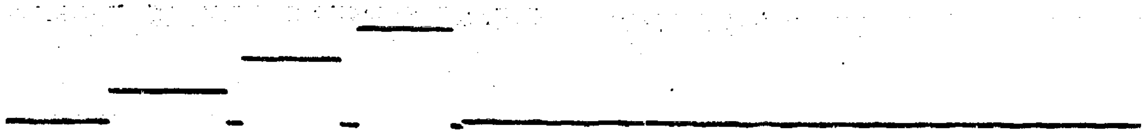
Pict. No. I4	Mach No. = .408	Av. Max. Pres. = 12.5 psig.
Run No. 703	N.T.-E.D. = -2.6 #	Av. Min. Pres. = -5.7 psig.
Config. C2-E1-N1-V4A	Fuel Flow = 160 pph.	Freq. = 88 cps.



Pict. No. J4	Mach No. = .408	Av. Max. Pres. = 16.6 psig.
Run No. 708	N.T.-E.D. = 20.9 #	Av. Min. Pres. = -4.5 psig.
Config. C2-E1-N1-V4A	Fuel Flow = 160 pph.	Freq. = 78 cps.



Pict. No. K4	Mach No. = .408	Av. Max. Pres. = 23.0 psig.
Run No. 712	N.T.-E.D. = 33.1 #	Av. Min. Pres. = -5.4 psig.
Confog. C2-E1-N1-V4A	Fuel Flow = 260 pph.	Freq. = 72 cps.



Calibration of pressure transmitter at ambient temperature (80° F.)

Combustion chamber pressures for engine with augmenter, submerged inlet cowl, .010 valves normally closed, 14% valve area block at M = .408.

Figure 18